© *The Pakistan Development Review*
62:2 (2023) pp. 223–234
DOI: 10.30541/v62i2pp.223-234

Impact of Kitchen Structure and Cookstove Technology on Respiratory Health of Rural Women Exposed to Indoor Air Pollution in Khyber Pakhtunkhwa, Pakistan

ABEDULLAH and MUHAMMAD TANVIR

Incomplete combustion of polluting fuels (PF) is a major source of indoor pollution which poses severe risks of acute respiratory infections to women's health such as cough, phlegm, and breathing difficulties. This article investigates the net impact of kitchen structural factors including the location of the kitchen and number of windows in the kitchen and cookstove technology on acute respiratory symptoms of rural women involved in cooking practices. A household survey was conducted to collect primary data from 250 rural households in Khyber Pakhtunkhwa province. Around 66 percent of rural households exclusively used polluted fuel for cooking which caused 4 respiratory symptoms among poor women. The results of the Poisson regression model revealed that the use of polluted energy in the enclosed kitchen was four times more responsible for respiratory symptoms than in the open kitchen; while an improved cookstove in the enclosed kitchen was three times more effective in controlling respiratory involvements. Concerted efforts are required to adopt short-term mitigation strategies such as improved stoves and efficient kitchen design.

Keywords: Polluted Fuel, Indoor Air Pollution, Kitchen Structures, Improved Stove, Women's Respiratory Symptoms, Pakistan

INTRODUCTION

Indoor air pollution (IAP) is ranked among the top ten global threats to human health as it contributes 2.7 percent to the global burden of diseases. Incomplete combustion of polluting fuels (PF) such as wood, crop residues, and dung cake in inefficient cookstoves under poorly ventilated conditions is a major source of IAP (WHO, 2006). Almost 73 percent of rural and 11 percent of urban households are depending on PF for cooking (PDHS, 2017-18).

According to the World Health Organisation, more than half of the global burden of respiratory illnesses is borne by poor people in developing countries (WHO, 2011). More than 3 billion of the world's population, comprising approximately 90 percent of rural households in low- and middle-income countries, primarily depend on PF for

Abedullah <abedullah@pide.org.pk> is Chief of Research, Pakistan Institute of Development Economics (PIDE), Islamabad. Muhammad Tanvir is Self-employed.

Authors' Note: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. The author(s) received no financial support for the research, authorship, and/or publication of this article.

cooking and heating due to inaccessibility and unaffordability to cleaner sources of energy (CF) i.e., gas and electricity (WHO, 2007). IAP results in around 4 million deaths annually and 110 million disability-adjusted life years (DALYs) (Uzun, et al. 2003; WHO, 2009a) and it accounts for 28,000 deaths per year and 40 million cases of acute respiratory illnesses in Pakistan alone (World Bank, 2006).

IAP is considered a major source of morbidity and mortality among women due to their high levels of exposure during indoor activities particularly cooking. Therefore, there is a need to conduct a comprehensive health assessment of rural women's respiratory symptoms for designing sustainable intervention strategies.

Polluted indoor air contains multiple detrimental pollutants including particulate matter (PM), poisonous gases (e.g., carbon monoxide (CO), nitrogen oxides, and sulfur dioxide), polycyclic aromatic hydrocarbons (PAH), and volatile organic compounds (VOC). Though particulate matter ranging in size between PM_{10} and $PM_{2.5}$ is an invisible killer in the kitchen as it can easily pass through the nose and can penetrate lung tissues (Mondal and Chakraborty 2015; WHO 2006, 2007, 2009b). Prolonged exposure to harmful indoor pollutants causes several acute respiratory infections such as cough, phlegm, and breathing difficulties that lead to chronic respiratory diseases such as obstructive pulmonary diseases, pneumonia, tuberculosis, lung cancer, etc (WHO, 2006; 2011). Hence, IAP is a major contributor to respiratory involvement among rural households.

Among South Asian countries, Pakistan is the third largest user (81 percent) of PF after Bangladesh (89 percent) and India (82 percent) (WHO, 2009b). Furthermore, the country is ranked first in South Asia in terms of the highest DALYs (9/1000 capita per year) due to IAP (WHO, 2009a). Few studies have evaluated the influence of polluting sources of energy on poor women's health in Bangladesh, Cameron, India, Mexico, Nigeria, and Turkey (Uzun, et al. 2003; Alim, et al. 2014; Ngahane, et al. 2015; Mohapatra, et al. 2018; Desalu, et al. 2010; Regalado, et al. 2006). However, these studies have only assessed a positive association between PF and women's respiratory illnesses. Respiratory symptoms may also vary with various risk amplifying factors such as traditional mud cookstove (TCS), enclosed/indoor kitchen, long cooking hours, and risk-mitigating factors such as improved cookstove (ICS), open/outdoor kitchen or enclosed kitchen with windows, diversified household chores, women's education, and household income (Sota, et al. 2018; Deepthi, et al. 2019; Sharma and Jain, 2019; Semenya and Machete, 2020; Whitehouse, et al. 2018). Recent studies have observed that ICS and open/ventilated kitchens are found to be major factors in reducing concentrations of poisonous gases, PM, PAH, and VOC (Deepthi, et al. 2019; Sharma and Jain, 2019; Semenya and Machete, 2020; Whitehouse, et al. 2018). ICS and kitchen characteristics may greatly reduce the impact of IAP on women's respiratory symptoms.

Previous studies have extensively explored factors affecting cooking fuel choices and children's respiratory health risks in Pakistan. The literature review reveals that there are only three studies have assessed women's health impacts of IAP in Pakistan. Khushk, et al. (2005) have observed that ICS reduces IAP-related acute symptoms among exposed women in Sindh province but the results were not statistically significant due to the small sample. Akhtar, et al. (2007) have found a 7 percent higher risk of chronic bronchitis among PF-using women of Khyber Pakhtunkhwa province. Rabbani, et al. (2017) have documented a 41 percent higher prevalence of tuberculosis in biomass-using women in Sindh.

Comparing only a few respiratory symptoms between PF and CF-exposed women without controlling for confounding factors does not allow a conclusive statement about the net health effects of IAP. Moreover, net health assessment after including cook stove types (TCS vs ICS) and kitchen structural factors including the location of the kitchen (indoor vs outdoor) and the number of windows in the kitchen, among other confounders has received little attention in the scientific literature. In light of this background, this study unveils the net effects of cookstove type and kitchen structures, among other factors on respiratory symptoms of poor and vulnerable women exposed to IAP in the rural Khyber Pakhtunkhwa (KPK) province of Pakistan.

METHODS

Sampling Procedure

KPK is the third largest province of Pakistan, with 30.52 million inhabitants which is 15 percent of the total national population (GoP, 2017). This province was selected because it has the highest poverty incidence (41 percent), and approximately 93 percent of its rural households depend on PF for their cooking needs (Akhtar, et al. 2007; Rabbani, et al. 2017; GoP, 2017; Nasir, et al. 2015). A household survey was conducted in rural areas of KPK by employing a four-stage sampling technique. During the first stage, Abbottabad and Haripur districts were purposively selected as their rural population varies between 87-97 percent and firewood is the primary fuel because of free and easy access to forests (Jan, 2017). Some households also use CF including liquefied petroleum gas (LPG). Moreover, Sarhad Rural Support Programme (SRSP) and a few NGOs have initiated ICS dissemination programs in these districts. In the second stage, all three tehsils were selected in each district. In the third stage, 2 union councils (administrative units) were randomly selected from each tehsil. Finally, 21 households were randomly selected from each union council, making a random sample of 252 households. However, the final analysis includes 250 observations by dropping 2 outliers.

The Questionnaire, Variables, and Interviews

To obtain primary data from selected households, this study adapted a WHO household questionnaire (WHO, 2008) for the evaluation of household energy and socioeconomic information and a standard American Thoracic Society (ATS) questionnaire (American Thoracic Society, 1991) for self-reported respiratory symptoms. The final questionnaire comprises four sections: socioeconomic status such as age, gender, family size, education, and income; types of primary energy used for cooking (firewood, crop residues, animal dung, LPG, and kerosene oil) during the last one month; exposure factors including daily cooking duration (time spend in cooking three meals by all women of a household and is measured in hours per day), diversified household chores (number of women involved in cooking practices); environmental factors comprising of types of the kitchen (open/outdoor vs enclosed/indoor), number of windows in the enclosed kitchen, types of cookstove (TCS vs ICS); and five acute respiratory symptoms such as eye irritation, headache, dizziness, cough, and breathlessness experienced during the last month. Information on socio-economic status was inquired from the household head, while information on the rest of the three sections was asked from all non-smoking females older than 15 years and involved in cooking practices. Women's health symptoms were aggregated at the household level as the household was considered a unit of analysis. Face-to-face interviews were conducted from November 2018 to January 2019 by a trained team of enumerators supervised by the second author. Due to the high level of illiteracy, verbal informed consent was taken from all respondents and was recorded before the survey.

Estimation Method

To evaluate the net impacts of ICS and kitchen structures on the prevalence of respiratory symptoms among rural women of KPK province, the Poisson regression estimator is used as it is more appropriate for a count outcome variable. The frequency of self-reported symptoms by women represents a count of respiratory symptoms. The Poisson distribution is illustrated as (Cameron, 1998):

$$Prob\ (Y_i = y_i/x_i) = \frac{e^{-\lambda_i}\lambda_i^{y_i}}{y_i\,!} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

where, y_i is a count of five respiratory symptoms faced by all women of the *i-th* household during the last month and it varies across households $(i = 1, \ldots., 250)$. Poisson distribution is assumed to have a conditional mean (λ_i), which in turn depends on a vector of exogenous variables (x_i) aggregated at the household level. The most common functional form of λ_i used in the literature is a log-linear model, which can be expressed as:

$$ln\ \lambda_i = \beta_i x_i + \epsilon_i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Where β_i is a vector of respective coefficients, x_i represents the household, women, exposure, and environmental characteristics, and ϵ_i stands for unobservable household-specific random effects.

RESULTS

Descriptive Statistics

For descriptive analysis, we divided our households into two groups (PF vs CF users) and compared their mean values using t- and chi-square tests for continuous and categorical variables, respectively. Mean values are reported with standard deviations in parentheses, as shown in Table 1. Out of 250 surveyed households, 166 (66.4 percent) households exclusively used firewood and 84 (33.6 percent) used an alternative CF such as LPG for cooking during the last month. Households using PF and CF had 34.80 percent and 20.00 percent enclosed kitchens, respectively. However, CF households had slightly more windows in their kitchen. Similarly, a larger proportion (5.2 percent) of CF households used ICS as their primary stove. The average daily exposure of women to IAP during cooking with PF was 4.81 hours/day, which is significantly higher than those using CF (3.84 hours/day). On average 2.18 women were involved in kitchen work in PF households than their counterparts (2.50).

Table 1

Characteristics of Polluted and Clean Fuel Using Households

Variables	Polluted fuel (PF) users (N=166)	Clean fuel (CF) users (N=84)
Enclosed kitchen (%)	34.80***	20.00
Windows in kitchen (No.)	1.08*	1.35
	(0.88)	(1.41)
Improved cookstove (ICS) (%)	3.40***	8.60
Cooking duration (hours per day)	4.81***	3.84
	(1.24)	(0.70)
Diversified household chores (No. of women involved in cooking practices)	2.18***	2.50
	(0.88)	(0.85)
Women education (years of schooling)	6.70***	5.25
	(3.86)	(3.30)
Household size (No.)	6.62***	5.09
	(2.27)	(1.87)
Household income (PKR/month)	34,398.29***	55,058.10
	(12541.24)	(30734.30)
Haripur district (%)	84.00***	16.00
Abbottabad district (%)	48.80**	51.20
Acute respiratory symptoms (No.)	4.26***	2.67
	(1.30)	(0.96)

***, **, and * represent significant differences in variables between polluted and clean fuel users at 1 percent, 5 percent, and 10 percent, respectively.

Notes: t-tests are used for continuous and chi-square tests for categorical variables to identify differences in mean values. Mean values are reported with standard deviations in parentheses.

The average schooling of females belonging to PF households was significantly higher (6.70) compared to their counterparts (5.25). Similarly, the average size of PF households was 6.62, which was significantly larger than that of CF households (5.09). However, the average monthly income of CF households was significantly higher (PKR 55,058) compared to their counterparts (PKR 34,398). The distribution of households across energy types and districts is given at the bottom of this table. On average, 84 percent and 16 percent of households in the Haripur district were using PF and CF, respectively. However, in Abbottabad, about 49 percent and 51 percent of households were using PF and CF, respectively.

The average frequency of short-term respiratory involvements was 4.26 symptoms for women exposed to wood smoke, which was 73 percent higher than that faced by their counterparts using CF (2.67 symptoms). Figure 1 further illustrates the distribution of respiratory symptoms across sources of energy. The majority of women using CF reported a count of 2, 3, and 4 respiratory symptoms, while women using PF reported a significantly higher frequency of 4, 5, 6, and 7 symptoms. Moreover, women in PF households reported more than the twofold prevalence of 3 symptoms than their counterparts. Figure 2 shows that a higher prevalence of respiratory symptoms was reported by women of PF households in both districts.

Fig. 1. Frequency of Incidence of Respiratory Symptoms Faced by Polluted and Cleaner Energy Using Women

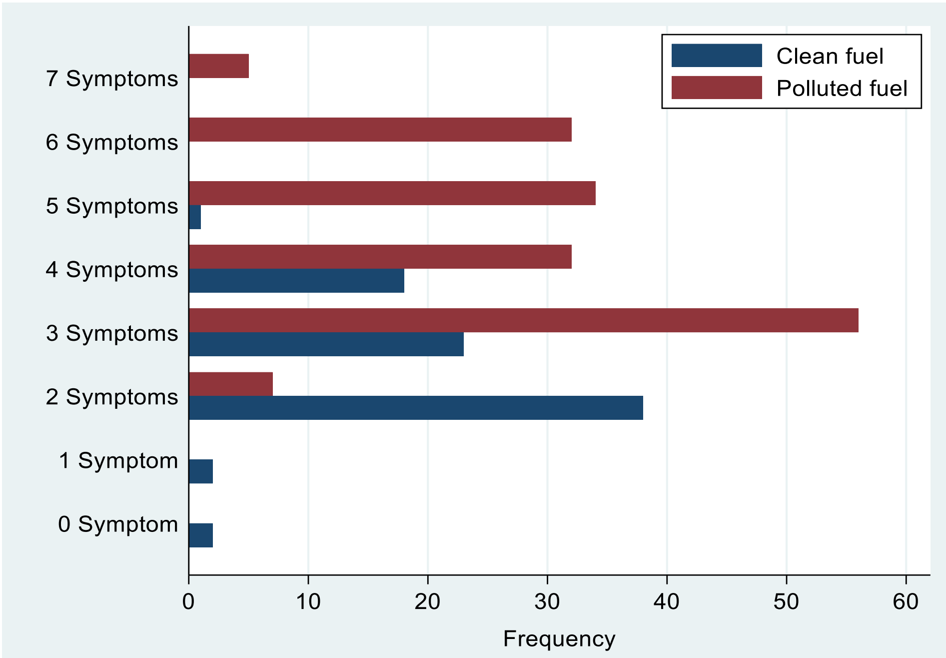
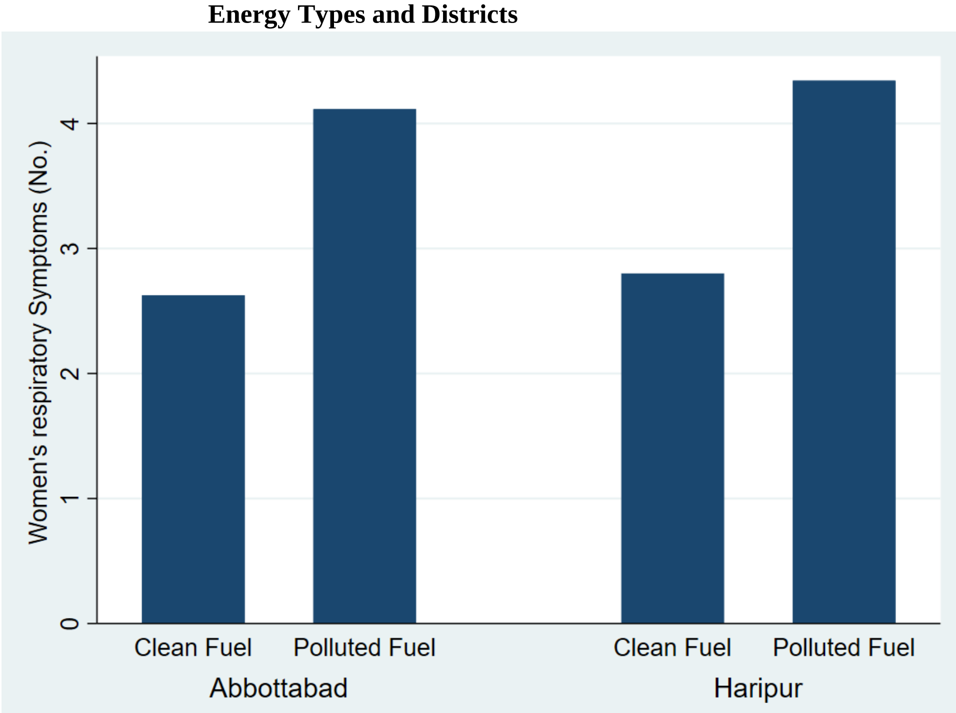


Fig. 2. Distribution of Women's Respiratory Symptoms across Energy Types and Districts



Regression Results

The results of the Poisson regression estimator are reported under Model I in Table 2. In column 1, the marginal effect of PF was positive and statistically significant, implying that women cooking with firewood were suffering from 1.721 more acute respiratory symptoms than their cleaner energy counterparts. Similarly, an enclosed kitchen was responsible to increase 1.146 respiratory symptoms among women compared to those cooking in an open kitchen. Nonetheless, an increase in the number of windows in the kitchen led to reducing respiratory involvement by 0.203 symptoms among poor women. ICS was also reducing acute health effects by 0.601 symptoms than TCS. Longer cooking hours were significantly increasing women's respiratory symptoms by 0.402, while diversified household chores were significantly decreasing symptoms by 0.132. Socioeconomic variables such as women's schooling years and household income significantly reduced the symptoms, while the district dummy was found to have insignificant impacts on women's health.

Table 2

Factors Affecting Women's Respiratory Symptoms

Variables	Model I		Model II	
	Marginal Effects	Scaled Coefficients[a]	Marginal Effects	Scaled Coefficients[a]
Polluted Fuel (PF) dummy	1.721*** (0.401)	0.190** (0.071)	–	–
Enclosed kitchen dummy	1.146*** (0.304)	0.601*** (0.103)	1.220* (0.554)	–0.032 (0.127)
Windows in kitchen	–0.203* (0.121)	–0.224*** (0.056)	–0.183* (0.110)	–0.081** (0.037)
Improved cookstove (ICS) dummy	–0.601** (0.311)	–0.763*** (0.123)	–	–
Cooking duration	0.402*** (0.120)	0.401*** (0.042)	0.504*** (0.150)	0.412*** (0.052)
Diversified household chores	–0.142* (0.101)	–0.203*** (0.032)	–0.313* (0.153)	–0.208*** (0.049)
Women education	–0.027* (0.015)	–0.143** (0.055)	–0.020 (0.040)	–0.135*** (0.043)
Household income	0.002** (0.001)	–0.003*** (0.001)	0.000 (0.000)	–0.001* (0.000)
Haripur district dummy[b]	0.134 (0.262)	0.000 (0.086)	0.101 (0.246)	0.063 (0.079)
Polluted fuels in enclosed kitchen	–	–	1.405*** (0.400)	0.715*** (0.106)
Polluted fuels in open kitchen	–	–	1.036** (0.503)	0.231** (0.114)
Improved stove in enclosed kitchen	–	–	–0.925** (0.412)	–0.787*** (0.121)
Improved stove in open kitchen	–	–	-0.401 (0.504)	-0.215* (0.123)
Intercept	–	–	–	–
Model Statistics				
Log likelihood	–408.06		–407.76	
LR χ^2 (9/10)	102.45***		103.05***	
Observations	250		250	

***, **, and * represent the significance levels at 1 percent, 5 percent, and 10 percent, respectively.

Note: Standard errors are given in parentheses.

[a]Scaled coefficients represent coefficients scaled by sample mean and standard deviation.

[b]Abbottabad district is a comparison category.

On the basis of marginal effects, it is hard to compare and conclude about major health risk amplifying and mitigating factors as they were measured on a different scale of measurements. To overcome this problem, we estimated standardised scale coefficients and reported them in column 2 of Table 2. Our results revealed that the enclosed kitchen was found to be the highest respiratory risk (0.601) intensifying factor, followed by cooking duration (0.401) and PF (0.190). Contrarily, ICS (–0.763) had the highest contribution to mitigating respiratory health symptoms, followed by diversified household chores (–0.203), windows in the kitchen (–0.224), and women's education (–0.143).

Further, to investigate the impacts of PF/ICS in connection with open and enclosed kitchens on women's respiratory symptoms, the respective interaction terms were generated and are reported in Model II of Table 2. According to standardised scale coefficients, PF burning in the enclosed kitchen was a major risk factor by increasing women's respiratory involvement (0.715 symptoms), followed by cooking duration (0.412), and use of PF in the open kitchen (0.231). Nonetheless, cooking with ICS in an enclosed kitchen was a major risk mitigating factor (–0.787), followed by diversified household chores (–0.208), women's education (–0.135), and the number of windows in the kitchen (–0.081).

DISCUSSION

This is the first study to evaluate the net health impacts of IAP after controlling for confounding factors such as kitchen structure, stove types, energy types, pollution exposure, socioeconomic, and geographical characteristics. In both districts of KPK, the majority (66.4 percent) of households are still using fuelwood due to its cheap and easy accessibility (Jan et al., 2017). IAP from PF burning induced about 2 additional acute respiratory symptoms among directly exposed women, aged between 15-55 years, compared with those cooking with alternative CF. This finding is consistent with earlier work from Bangladesh, Cameron, India, Guatemala, Malawi, Mexico, Mozambique, Nigeria, Pakistan, and Turkey (Uzun, et al. 2003; Alim, et al. 2014; Ngahane, et al. 2015; Mohapatra, et al. 2018; Desalu, et al. 2010; Regalado, et al. 2006; Deepthi, et al. 2019; Whitehouse, et al. 2018; Akhtar, et al. 2007; Rabbani, et al. 2017). These studies only showed a positive association between acute and chronic respiratory diseases and hazardous pollutants released due to incomplete combustion of PF. In contrast, our findings contributed by measuring the exact acute health effects of PF.

One of the major strengths of our study is the evaluation of kitchen structures and cookstove technology on IAP-related women's symptoms. Our study demonstrated that women, who cooked in an enclosed kitchen, were suffering from relatively 1 extra respiratory symptom than their counterparts. One possible explanation for this finding could be that an enclosed kitchen is attributed to intensifying concentrations of health-damaging indoor air pollutants. This finding is consistent with recent case-control studies conducted in India and South Africa (Deepthi, et al. 2019; Sharma & Jain, 2019; Semenya & Machete 2020). Deepthi, et al. (2019) and Sharma and Jain (2019) reported higher deposition of PM in the respiratory tract of women cooking in an enclosed kitchen in India. Another study from South Africa observed a higher prevalence of acute symptoms among households having cemented and roofed kitchens (Semenya &

Machete, 2020).[13] However, these studies did not control for confounding factors and failed to estimate the net impact of the enclosed kitchen on respiratory health.

Installation of windows in the kitchen may not only improve ventilation but may also mitigate exposure to IAP as recommended in previous studies (Sharma & Jain 2019; Semenya & Machete 2020). Our findings confirmed that an increase in the number of windows in the kitchen reduced the impacts of IAP on women's health. Similarly, women cooking with ICS technology observed a reduction in about 1 respiratory symptom compared with those cooking with TCS. Rosenthal, et al. (2018) highlighted that inefficient open-fire burning of PF increased the exposure of women during cooking. Moreover, other studies reported a 20–50 percent reduction in PM and CO concentrations due to ICS (Sota, et al. 2018; Sharma & Jain 2019; Whitehouse, et al. 2018; Khushk, et al. 2005; Estévez-García, et al. 2020). Hence, a conducive kitchen environment is necessary for women's health and productivity.

Another strength of our study is the measurement of women's exposure to IAP. For this, we asked about daily cooking duration and diversified household chores. We found that a one-hour increase in daily cooking of three meals increased women's respiratory involvement by 0.4 symptoms. Estévez-García, et al., (2020) explained that women substantially suffered from polluted smoke as they spent most of their time in the microenvironment of the kitchen. On the other hand, the involvement of more females in cooking practices leads to distributing their household chores that were observed to decrease health burden by reducing their exposure to IAP.

Our findings demonstrated that educated women could better understand the consequences of PF and could better adopt mitigating and preventive measures to lessen the burden of respiratory symptoms. However, the impact of household income was very negligible in our study. One possible explanation could be that an enclosed kitchen and the use of cleaner energy and ICS are also reflecting household economic status, as also pointed out by earlier studies (Rabbani, et al. 2017). The district variable was insignificant, implying that women's health status was almost the same in both districts.

Another major strength of our findings is the identification of major health risk amplifying and mitigating factors. On the basis of standardised scale coefficients in Model 1, we found that the enclosed kitchen was the major culprit for increasing IAP-related respiratory symptoms, while ICS was the major short-term remedy for reducing symptoms. Another important contribution of our study is the inclusion of unique interaction terms in Model II. We evaluated the use of PF in the enclosed or open kitchen and inferred from standardised scale coefficients that PF was three-fold more responsible for developing respiratory symptoms compared to when it was used in an open kitchen. This implies that the use of PF either in enclosed or open kitchens is perilous for women's health. Nonetheless, we found the use of ICS technology in an enclosed kitchen was about four-fold more effective in controlling respiratory involvement than that used in an open kitchen. It could be due to high level of IAP in the enclosed kitchen than that in the open kitchen (Deepthi, et al. 2019; Sharma & Jain 2019; Semenya & Machete 2020). Regalado, et al. (2006) found 27 percent higher production of phlegm among women cooking with PF in TCS.

These findings are not free from limitations as we only focused on a few acute symptoms and ignored chronic diseases associated with IAP. Future studies should measure real-time exposure to IAP and conduct medical examinations of women, cooking with PF, for rigorous policy formulation.

CONCLUSION

This study significantly contributes to global evidence by identifying major IAP-related health risk aggravating and mitigating factors. We concluded that enclosed kitchens mainly increased IAP-related respiratory symptoms among rural women of KPK, while ICS and ventilated kitchens significantly minimised symptoms in three possible ways: by reducing IAP generated due to incomplete fuelwood burning, by reducing IAP intensified due to enclosed kitchen, and by reducing women exposure to IAP. However, concerted efforts are required to adopt short-term mitigation strategies such as improved ICS and efficient kitchen design. Moreover, there is a need to be aware poor women of the health risks of biomass fuels. Shifting rural households to affordable and cleaner energy (sustainable development goal 7) is a long-term effective strategy but demands huge investment by developing countries.

REFERENCES

Akhtar T, Ullah, Z., Khan, M. H., & Nazli, R. (2007). Chronic Bronchitis in Women Using Solid Biomass Fuel in Rural Peshawar, Pakistan. *Chest, 132,*1472–1475.

Alim, Md A., Sarker, M. A. B., Selim S., Karim, Md R., Yoshida Y., & Hamajima, N. (2014). Respiratory involvements among women exposed to the smoke of traditional biomass fuel and gas fuel in a district of Bangladesh. *Environ Health Prev Med. 19,*126–134.

American Thoracic Society (1991). Lung function testing: selection of reference values and interpretative strategies. *Am Rev Respir Dis. 144,* 1202–1218.

Cameron, A. C. & Trivedi, P. K. (1998). *Regression analysis of count data*. New York, NY: Cambridge University Press.

Chen, T. & Liao H. (2018). The disease burden of indoor air pollution from use in China. *Asia Pac J Public Health, 30*(4), 387–395.

Deepthi, Y., Nagendra, S. M. S., & Gummadi, S. N. (2019). Characteristics of indoor air pollution and estimation of respiratory dosage under varied fuel-type and kitchen-type in the rural areas of Telangana state in India. *Sci Total Environ, 650,*616–625.

Desalu, O. O., Adekoya, A. O., & Ampitan, B. A. (2010). Increased risk of respiratory symptoms and chronic bronchitis in women using biomass fuels in Nigeria. *J Bras Pneumol*. *36,*441–446.

Estévez-García, J. A., Schilmann, A., Riojas-Rodríguez, H., Berrueta, V., Blanco, S., Villaseñor-Lozano, C. G., Flores-Ramírez, R., Cortez-Lugo, M., & Pérez-Padilla, R. (2020). Women exposure to household air pollution after an improved cookstove program in rural San Luis Potosi, Mexico. *Sci Total Environ*. *702,*1–12.

GoP (2017). 6th Population and housing census-2017. Government of Pakistan, Ministry of Statistics, Islamabad.

Jan, I., Ullah, S., Akram, W., Khan, N. P., Asim, S. M., Mahmood, Z., Ahmad, M. N., & Ahmad, S. S. (2017). Adoption of improved cookstoves in Pakistan: A logit analysis. *Biomass Bioenergy, 103,* 55–62.

Khushk, W. A., Fatmi, Z., White, F., Kadir, M. M. (2005). Health and social impacts of improved stoves on rural women: A pilot intervention in Sindh, Pakistan. *Indoor Air, 15*(5), 311–316.

Mohapatra, I., Das, S. C., & Samantaray, S. (2018). Health impact on women using solid cooking fuels in rural area of Cuttack district, Odisha. *J Fam Med Prim Care, 7,*11–15.

Mondal, N. & Chakraborty, D. (2015). Vulnerability of rural health exposed by indoor pollution generated from biomass and fossil fuels. *Mor J Chem*. *3*(2), 1–83

Nasir, Z. A, Murtaza, F., & Colbeck, I. (2015). Role of poverty in fuel choice and exposure to indoor air pollution in Pakistan. *J Integr Environ Sci*. *12*(2), 107–117.

Ngahane, B. H. M., Afane, Z. E., Chebu, C., Mapoure, N. Y., Temfack, E., Nganda, M., & Luma, N. H. (2015). Effects of cooking fuel smoke on respiratory symptoms and lung function in semi-rural women in Cameroon. *Int J Environ Occup Health, 21*(1), 61–65.

PDHS (2018). Pakistan demographic health survey 2017-18. National Institute of Population Studies, Islamabad, Pakistan.

Rabbani, U., Sahito, A., Nafees, A., Kazi, A., & Fatmi, Z. (2017). Pulmonary tuberculosis is associated with biomass fuel use among rural women in Pakistan: An age- and residence-matched case-control study. *Asia Pac J Public Health, 29*(3), 211–218.

Regalado, J., Perez-Padilla, R., Sansores, R., Ramirez, J. I. P., Brauer, M., Pare, P., & Vedal, S. (2006). The effect of biomass burning on respiratory symptoms and lung function in rural Mexican women. *Am J Respir Crit Care Med*. *74*(8), 901–905.

Rosenthal, J., Quinn, A., Grieshop, A. P., Pillarisetti, A., & Glass, R. I. (2018). Clean cooking and the SDGs: Integrated analytical approaches to guide energy interventions for health and environment goals. *Energy Sustain Dev. 42*,152–159.

Semenya, K. & Machete, F. (2020). Influence of kitchen structures on household exposure to firewood-induced volatile organic compounds in Senwabarwana villages. *Air Qual Atmos Health, 13*,1193–1201.

Sharma, D., & Jain, S. (2019). Impact of intervention of biomass cookstove technologies and kitchen characteristics on indoor air quality and human exposure in rural settings of India. *Environ Int*. *123,* 240–255.

Sota, C. de la, Lumbreras, J., Pérez, N., Ealo, M., Kane, M., Youm, I., & Viana, M. (2018). Indoor air pollution from biomass cookstoves in rural Senegal. *Energy Sustain Dev*. *43,* 224–234.

Uzun, K., Ozbay, B., Ceylan, E., Gencer, M., & Zehir, I. (2003). Prevalence of chronic bronchitis-asthma symptoms in biomass fuel exposed females. *Environ Health Prev Med. 8,* 3–17.

Whitehouse, A. L., Miyashita, L., Liu, N. M., Lesosky, M., Flitz, G., Ndamala, C., Balmes, J. R., Gordon, S. B., Mortimer, K., & Grigg, J. (2018). Use of cleaner-burning biomass stoves and airway macrophage black carbon in Malawian women. *Sci Total Environ*. *635,* 405–411.

WHO (2006). Fuel for life: Household energy and health. World Health Organisation, Geneva

WHO (2007). Indoor air pollution takes heavy toll on health. World Health Organisation, Geneva, Available at: http://www.who.int/mediacentre/news/notes/2007/np20/en/index.html

WHO (2008). World Health Organisation. Evaluation household energy and health interventions: A catalogue of methods,. Website. http://www.un-energy.org/publications/138-evaluating-household-energy-and-healthinterventions-a-catalogue-of-methods

WHO (2009a). Estimated deaths & DALYs attributable to selected environmental risk factors, by WHO Member State, Available from: http://www.who.int/ indoorair/health_impacts/burden_national/en/

WHO (2009b). Proportion of children living in homes using solid fuels. European Environment and Health Information System (ENHIS). http://www.euro.who.int/__data/assets/pdf_file/0006/97008/3.6.-Homes-with-solid-fuels-EDITED_layouted_V3.pdf?ua=1

WHO (2011). Indoor air pollution and health. World Health Organisation, Geneva; 2011.

World Bank (2006). Pakistan: Strategic country environment assessment. Volume 1. Report No. 36946-PK. Washington, DC.